Oh 4

52D10

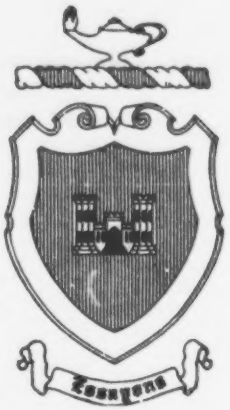
STUDENT WORKBOOK

OHM'S LAW

NEWARK PUBLIC LIBRARY

JUL 1 1986

U. S. GOVT. PUBS.
DEPOSITORY 375



JANUARY 1981

US ARMY ENGINEER SCHOOL - FORT BELVOIR, VIRGINIA

D 103. 120:

This publication supersedes Student Workbook, OHM'S LAW, 52B20-B-010-020, August 1976.

INTRODUCTION

The relationships of current, voltage, and resistance must be considered in every electric circuit. Direct current will flow only in a closed circuit which provides a continuous conducting path from the negative to the positive terminal of the voltage source. As discussed in this lesson, Ohm's Law shows the relstionships of voltage, current, and resistance in DC circuits.

The purpose of any electric circuit is to do some type of work. When voltage is applied to a resistance and causes current to flow work is done. The work done by an electric circuit is known as power.

This unit of instruction will help you to develop an understanding of simple direct current circuits. After completing this instruction, you will be able to:

1. Explain a simple electric circuit.
2. Explain Ohm's Law.
3. Explain the power law.

1. SIMPLE ELECTRIC CIRCUIT

A simple electric circuit is shown in Figure 1. Current flows from the negative (-) terminal of the battery through the lamp to the positive (+) terminal, and continues by going through the battery. As long as this path is unbroken, it is a closed circuit and current will flow (A of Figure 1). However, if the path is broken at any point, it is an open circuit and no current flows (B of Figure 1).

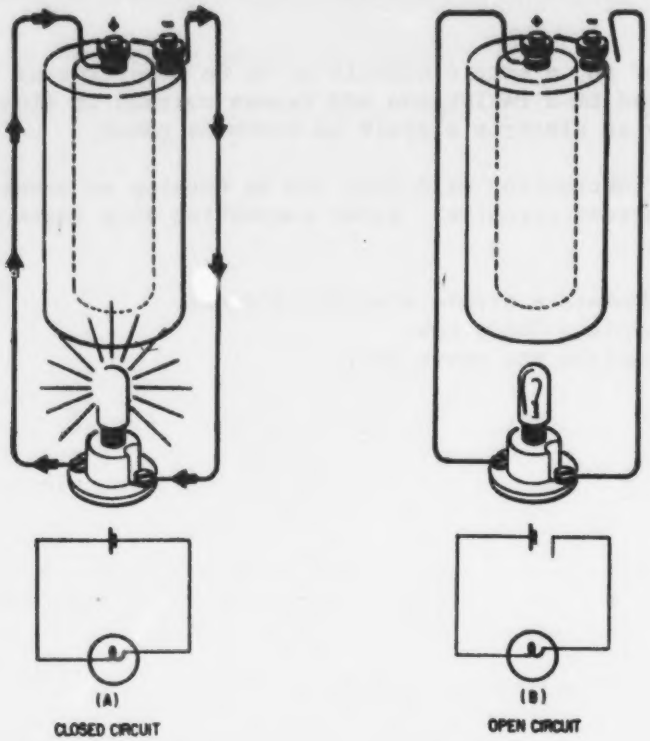


FIGURE 1 - SIMPLE ELECTRIC CIRCUIT

Notice in Figure 1, there are three components required to make the simple circuit - a voltage source (Battery), conductors (wires), and a resistive load (Bulb). In any electric circuit where electrons move around a closed loop, current, voltage, and resistance are present and power is consumed. The physical path for current flow is the actual circuit. The voltage causes the current to flow. The resistance opposes the flow of current, and the power is the amount of work done. If any two of these quantities are known, the other two may be determined. This is done by the use of Ohm's law and the power formula.

2. OHM'S LAW

The relationship of voltage, current, and resistance were first proved by George Simon Ohm, a German physicist. Using very poor and deficient apparatus, but the best to be had at the time, he performed a series of experiments which completely settled the questions of (1) the way electromotive force is distributed throughout a circuit, and (2) the relationships of voltage, current, and resistance.

a. Statement of Ohm's Law

Ohm's law may be stated in words as follows:

THE CURRENT IN AN ELECTRIC CIRCUIT IS DIRECTLY PROPORTIONAL TO THE VOLTAGE AND INVERSELY PROPORTIONAL TO THE RESISTANCE.

(1) Effect of Voltage on Current

"The current in an electric circuit is directly proportional to the voltage." Let us represent free electrons by an automobile that will not start (A of Figure 2). If a friend volunteers to assist by pushing the car, he would represent the pushing force, voltage. The road upon which the car is moving would represent opposition to the movement of the car, resistance. And last, the movement of the car would represent electron flow, current.

If the voltage decreases (B of Figure 2), the current also decreases. If the voltage increases (C of Figure 2), the current also increases.

(3) Effect of resistance on Current

"The current in an electric circuit is inversely proportional to the resistance." Again let us represent free electrons by a stalled automobile being pushed by a man (A of Figure 3). If the resistance increases and the voltage remains the same (B of Figure 3), the current decreases. If the resistance decreases and the voltage remains the same (C of Figure 3), the current increases.

b. Equations for Ohm's Law

Ohm's Law is a statement of the relationship of three values, these are:

VOLTAGE, CURRENT, and RESISTANCE. If the statement of Ohm's Law

were written down in a formula or mathmatical form three equations could be found. One for each value relating it to the other two values. These three formulas are as follows:

(1) E = IR, or voltage equals the current multiplied by the resistance. - DIRECT PROPORTION

(2) I = E/R, or current equals the voltage divided by the resistance. - INVERSE PROPORTION

(3) R = E/I, or resistance equals the voltage divided by the current. - INVERSE PROPORTION.

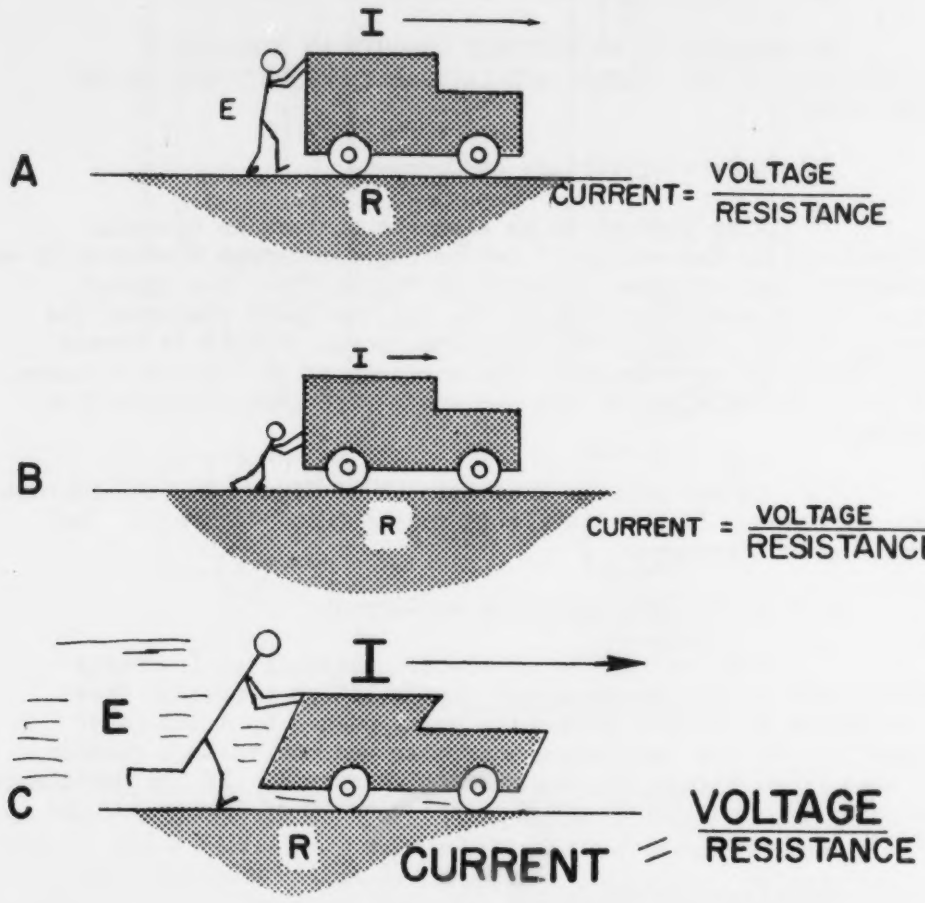


FIGURE 2 - EFFECT OF VOLTAGE ON CURRENT

READEX FICHE best copy available

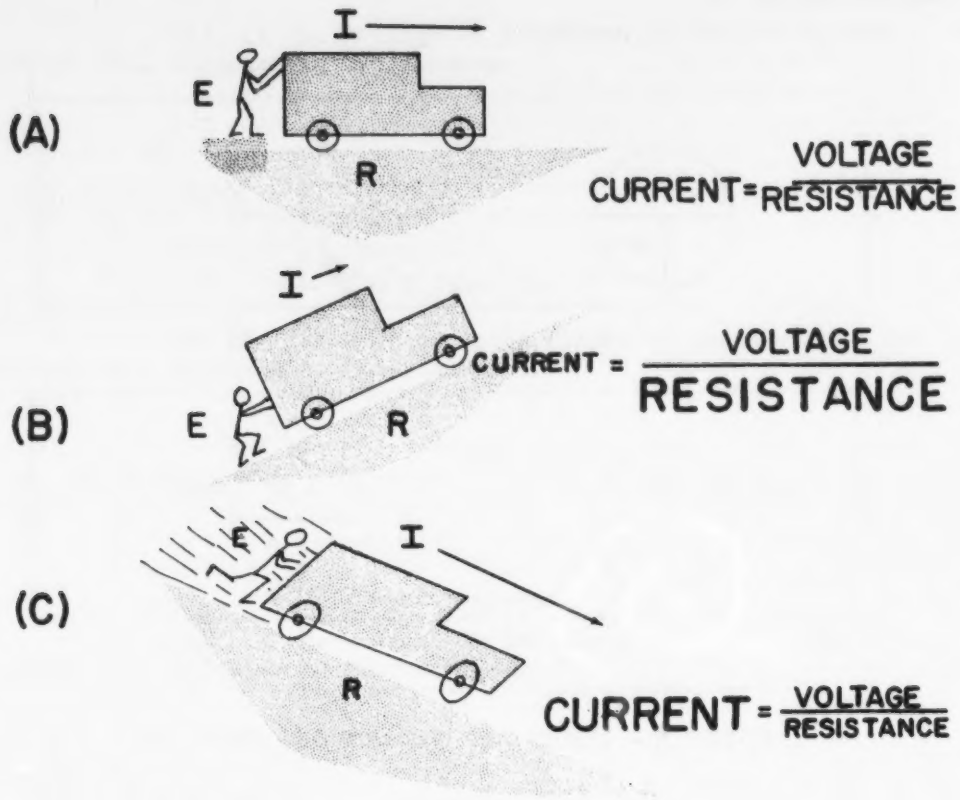


FIGURE 3 - EFFECT OF RESISTANCE ON CURRENT

c. Memory Method

The formulas for solving problems involving Ohm's Law must be learned. Do not bypass these formulas--they must be understood and remembered. A simple aid to memorizing Ohm's Law is shown in figure 4. Just think of the car used in Figures 2 and 3. On that car there was a wheel and on the wheel there was a tire. Draw a circle to represent the wheel, then write the word T-I-R-E inside of the circle as shown in A of Figure 4. If any one of the symbols is covered, the arrangement of the other two symbols forms the right hand side of the formula for determining the value of the covered symbol. Thus, if a finger is placed over (B of Figure 4), E/R remains and indicates that I is equal to E divided

by R. If R is covered (C of Figure 4), E/I remains and indicates that R is equal to E divided by I. In the same way, if E is covered (D of Figure 4), IR remains and indicates that E is equal to I multiplied by R.

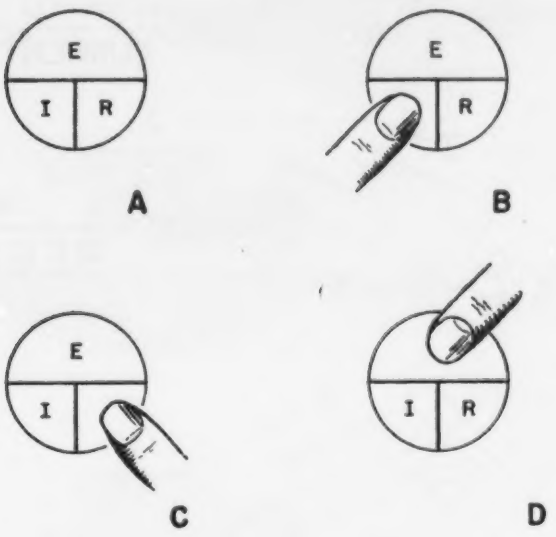
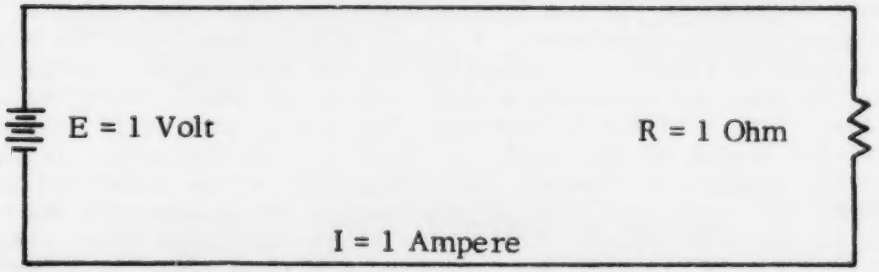


FIGURE 4 - MEMORY AID FOR LEARNING OHM'S LAW

d. Applications of Ohm's Law

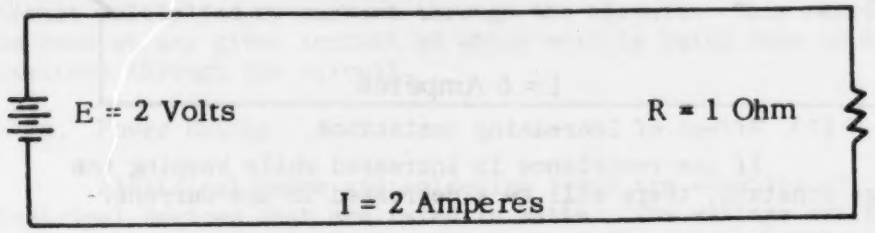
As was discussed previously, Ohm's Law states that THE CURRENT IN AN ELECTRIC CIRCUIT IS PROPORTIONAL TO THE VOLTAGE AND INVERSELY PROPORTIONAL TO THE RESISTANCE. Mathematically Ohm's Law can be stated as: <u>It takes one volt of electromotive force to push one ampere of current through one ohm of resistance</u>.



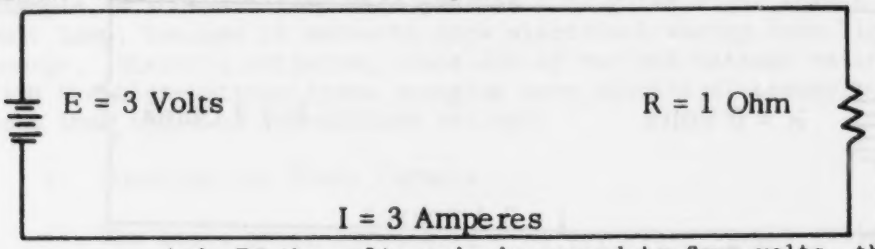
(1) Effect of Increasing Voltage

If the voltage is increased while keeping the resistance constant, there will be an increase in the current.

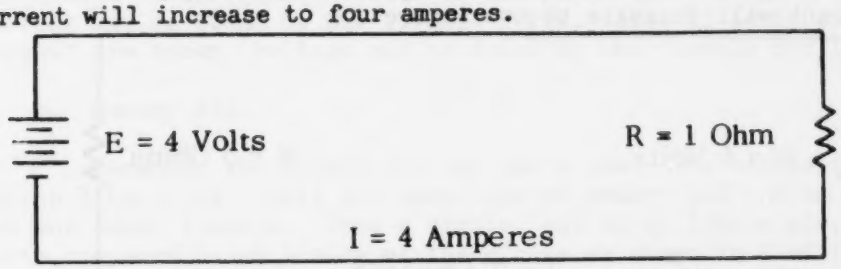
(a) If the voltage is increased to two volts, the current will increase to two amperes.



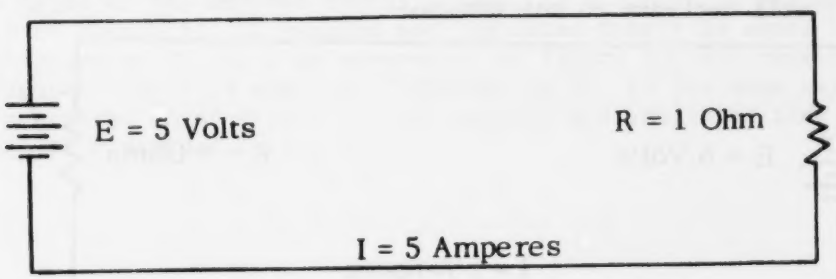
(b) If the voltage is increased to three volts, the current will increase to three amperes.



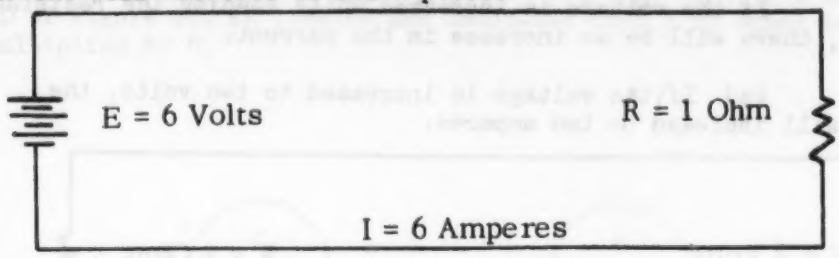
(c) If the voltage is increased to four volts, the current will increase to four amperes.



(d) If the voltage is increased to five volts, the current will increase to five amperes.



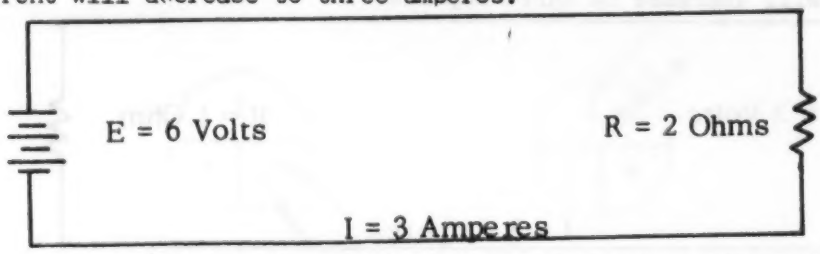
(e) If the voltage is increased to six volts, the current will increase to six amperes.



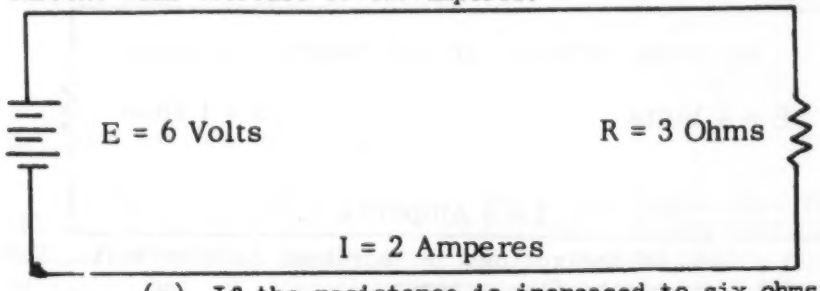
(2) Effect of Increasing Resistance

If the resistance is increased while keeping the voltage constant, there will be a decreased in the current.

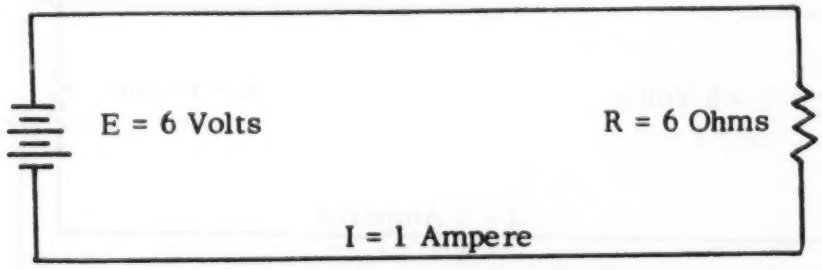
(a) If the resistance is increased to two ohms, the current will decrease to three amperes.



(b) If the resistance is increased to three ohms, the current will decrease to two amperes.



(c) If the resistance is increased to six ohms, the current will decrease to one ampere.



3. POWER FORMULA

Previously, you found that voltage is electromotive force and that voltage forces current to flow in a closed circuit. When voltage causes current to flow through a resistance, work is done. The rate at which this work is done is called power. The basic unit of power is the WATT, and it is equal to the voltage across a circuit multiplied by current through the circuit. This represents the rate at any given instant at which work is being done in moving electrons through the circuit.

a. Power Rating

Electrical lamps and soldering irons are examples of electrical devices that are rated in watts. The wattage rating of a device indicates the rate at which the device converts electrical energy into another form of energy, such as light or heat. For example, a 100-watt lamp will produce a brighter light than a 75-watt lamp, because it converts more electrical energy into light energy. Electric soldering irons are of various wattage ratings, with the high-wattage irons changing more electrical energy to heat than those of low-wattage ratings.

b. Equation for Power Formula

The basic power formula is P=IE or, power equals voltage multiplied by current. However if the power and voltage are known, current may be found by the formula I=P/E. Also if power and current are known, voltage may be found by the formula E=P/I.

c. Memory Aid

Remember the memory aid for Ohm's Law? The circle that was cut up like a pie. Well the same type of memory aid can be used for the power formula. Draw a circle, cut it up like a pie, then write the word P-I-E inside of the circle as shown in A of Figure 5. If any one of the symbols is covered, the arrangement of the other two symbols forms the right hand side of the formula for determining the value of the covered symbol. Thus, if a finger is placed over P (B of Figure 5), IE remains and indicates that P is equal to I multiplied by E. If I is covered (C of figure 5), P/E remains and indicates that I is equal to P divided by E. In the same way, if E is covered (D of Figure 5), P/I remains and indicates that E is equal to P divided by I.

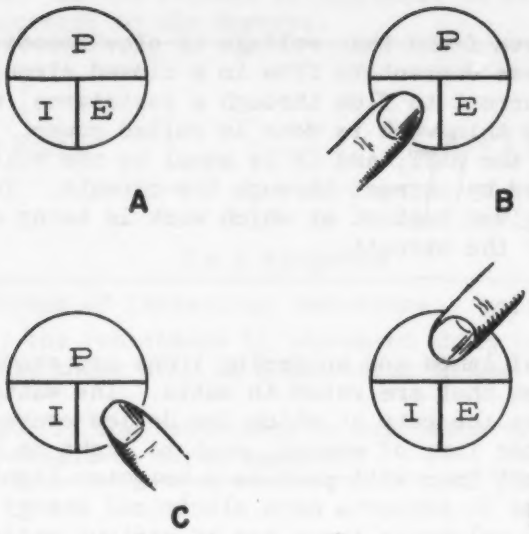
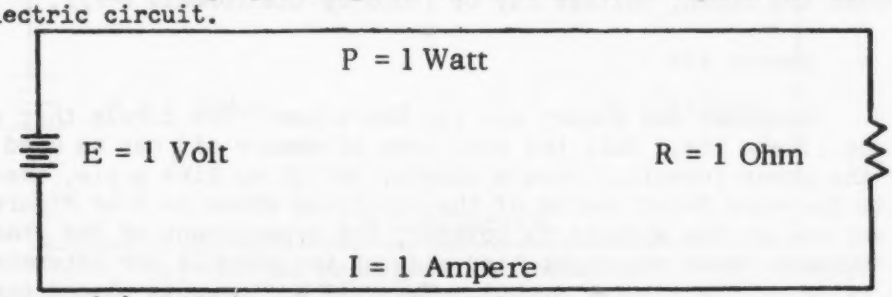


FIGURE 5 - MEMORY AID FOR LEARNING POWER FORMULA

d. Applications of the Power Formula

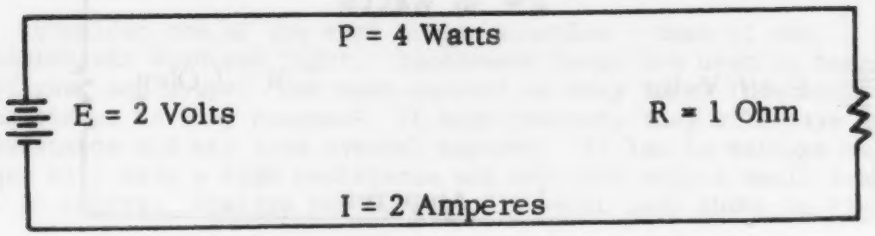
In previous examples, Ohm's law was demonstrated by simple circuit diagrams. Here are the same circuits again showing the effect of a changing voltage or resistance on the power of an electric circuit.



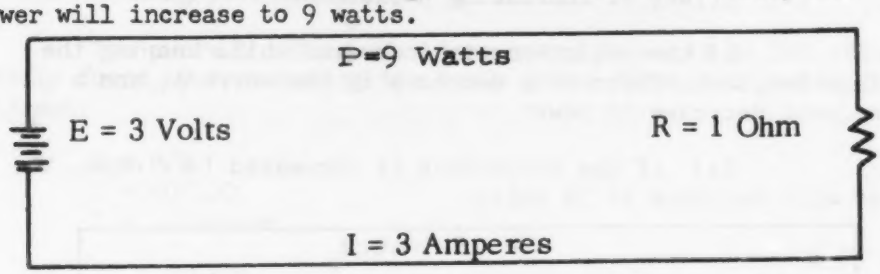
(1) Effect of Increasing Voltage

If the voltage is increased while keeping the resistance constant, there is an increase in current and a consequent increase in power. Notice if the voltage is doubled the power is doubled twice.

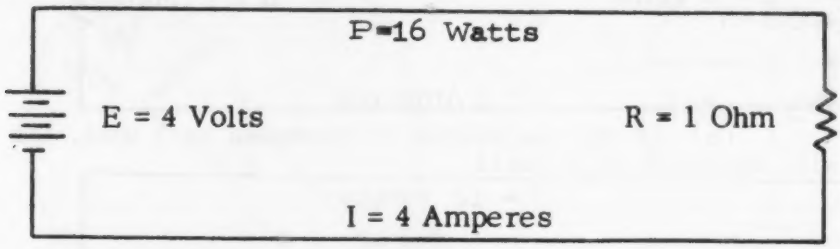
(a) If the voltage is increased to 2 volts, the power will increase to 4 watts.



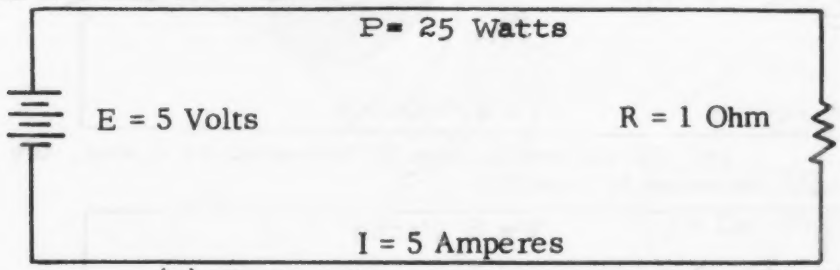
(b) If the voltage is increased to 3 volts, the power will increase to 9 watts.



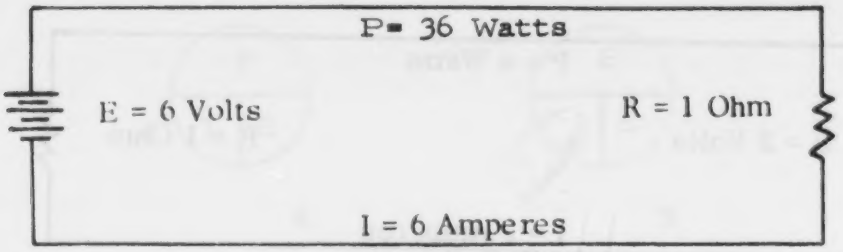
(c) If the voltage is increased to 4 volts, the power will increase to 16 watts.



(d) If the voltage is increased to 5 volts, the power will increase to 25 watts.



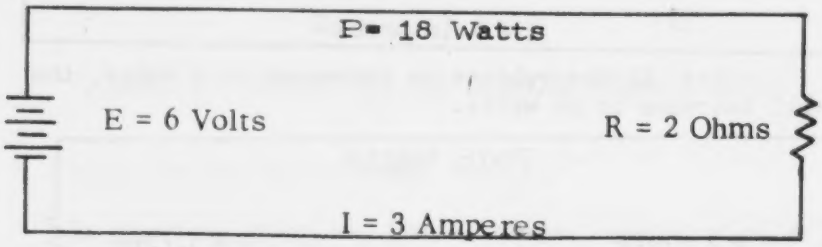
(e) If the voltage is increased to six volts, the power will increase to 36 watts.



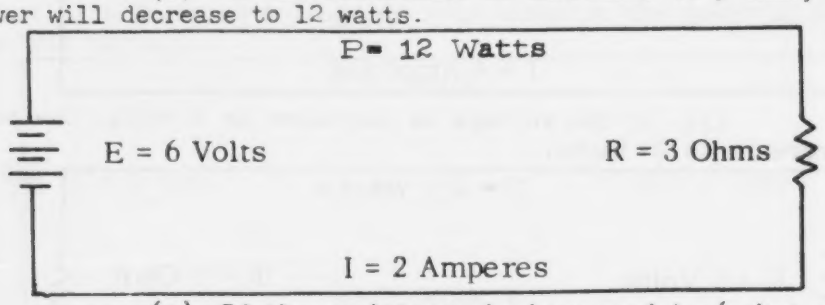
(2) Effect of Increasing Resistance

If the resistance is increased while keeping the voltage constant, there is a decrease in the current, and a consequent decrease in power.

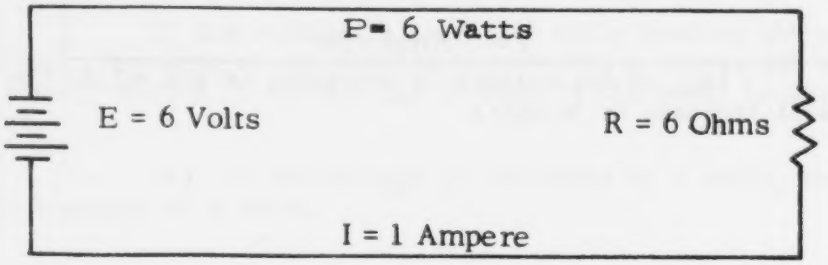
(a) If the resistance is increased to 2 ohms, the power will decrease to 18 watts.



(b) If the resistance is increased to 3 ohms, the power will decrease to 12 watts.



(c) If the resistance is increased to 6 ohms, the power will decrease to 6 watts.



4. PRACTICAL USE OF OHM'S LAW AND THE POWER FORMULA

Consider one of the most common examples - that of the incandesent electric light. Incadesent lamps are used in barracks, offices, and shops. How much current do they take? How much resistance do they possess? If high powered, they will have a low resistance and may draw several amperes. If low in wattage rating, they will have a high resistance and may take only a small fraction of an ampere. Analyze the 60-watt, 120-volt lamp shown in Figure 6.

a. Finding Current

The current rating of a lamp rated 60 watts at 120 volts is easily found by transposing the basic power formula to solve for current.

$I = P/E$
$I = 60/120$
$I = .5$ ampere

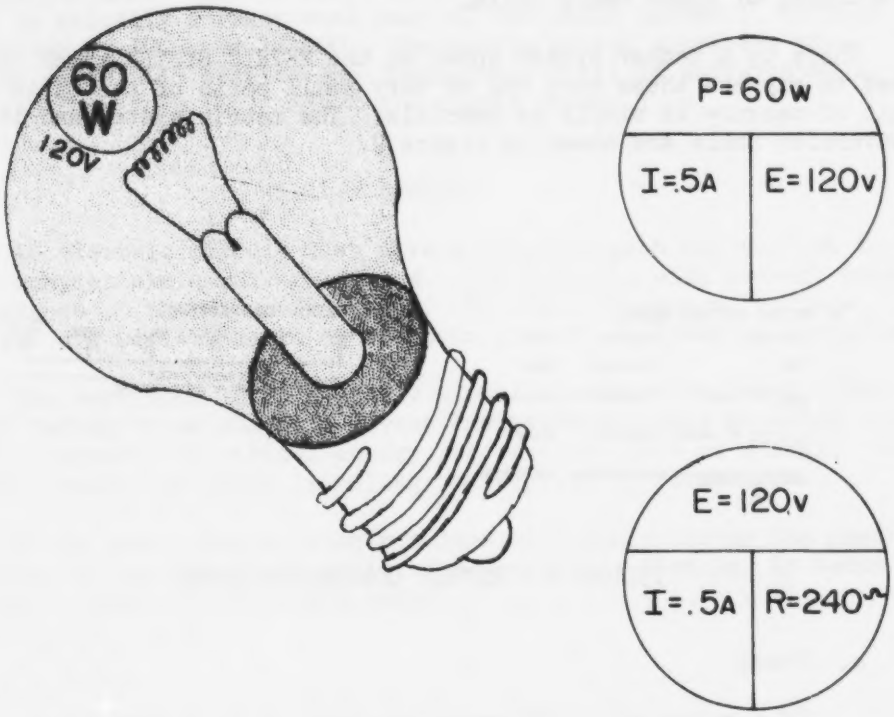


FIGURE 6 - PRACTICAL USE OF OHM'S LAW AND POWER FORMULA

b. Finding Resistance

The resistance of this lamp during normal operation may now be found by Ohm's law.

$R = E/I$
$R = 120/.5$
$R = 240$ Ohms

Thus, a 60-watt, 120-volt lamp draws a current of .5 ampere and has a hot resistance of 240 ohms.

5. METRIC SYSTEM

It is now known that voltage is measured in VOLTS, current is measured in AMPERES (or simply AMPS), and resistance is measured in OHM'S. Up to this point in the lesson only the basic units of measure have been used for simplicity. However, these values often appear as multipules of theses basic units and also as parts, or fractions, of these basic units.

There is a number system known as the METRIC SYSTEM which is used to express these very big or very small parts of the basic unit of measure as simply as possible. The metric system and its conversion table are shown in Figure 7.

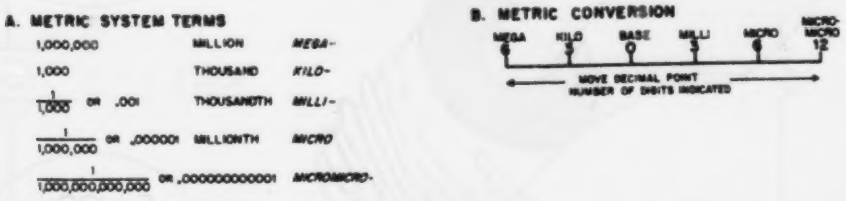

A. METRIC SYSTEM TERMS
1,000,000 MILLION MEGA-
1,000 THOUSAND KILO-
1/1,000 OR .001 THOUSANDTH MILLI-
1/1,000,000 OR .000001 MILLIONTH MICRO
1/1,000,000,000,000 OR .000000000001 MICROMICRO-
B. METRIC CONVERSION
MEGA KILO BASE MILLI MICRO MICRO-MICRO
6 3 0 3 6 12
MOVE DECIMAL POINT
NUMBER OF DIGITS INDICATED

FIGURE 7 - METRIC CONVERSION TABLE

a. Power

If a value of 10,000 watts was used up in a particular circuit it would be much easier to express this value in terms of t the metric system. The number 10,000 actually means 10 multiplied by 1000, or 10 thousand. In the metric system 1000 is given the name of "KILO" which when abbreviated is just simply "K." Therefore

10,000 watts could simply be written as 10KW.

b. RESISTANCE

The resistive load of a particular circuit may be in the thousands or even millions of ohms. As an example the resistance used in a certain circuit is 10,000 ohms, this seems very high but it is very common. Using the same thinking that was used for the power example (above), the value of 10,000 ohms would be equivalent to 10 K ohms.

c. Current

Whenever a small voltage is used to push current through a resistive load of the size used in the above example, that current is usually very small. Thousanths and possibly even millionths of an ampere are not unusual values of current when working with practical circuits. If one thousanth of an ampere (.001A) were being pushed through a load of some type it would be much easier to express this value in terms of the metric system. The number .001 is actually a fractional part of the whole number 1, in this 1 divided by 1000, or 1/1000. The metric system expresses this number as "MILLI" meaning one thousanth. Milli is abbreviated as "m" and therefore .001 amps would simply become 1 ma.

SUMMARY

An electric circuit must have a complete path for current to flow and contain a voltage source. All circuits will present some resistance to the flow of current. The relationship of voltage, current and resistance in an electric circuit is known as Ohm's law.

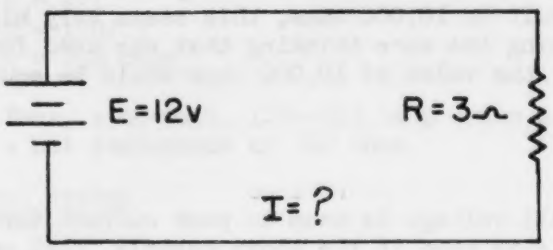
The work done in an electric circuit is known as power. The power rating of an electric device indicates the rate at which the device converts electrical energy into another form of energy. The basic formula for power is voltage multiplied by current.

It is best, when solving problems with Ohm's law or the power formula, to use the basic units of measurement, that is, in terms of volts, amperes, ohms, and watts.

STUDY QUESTIONS AND PRACTICE PROBLEMS

1. Voltage is that pressure used to push electrons, or _____, through a resistance.

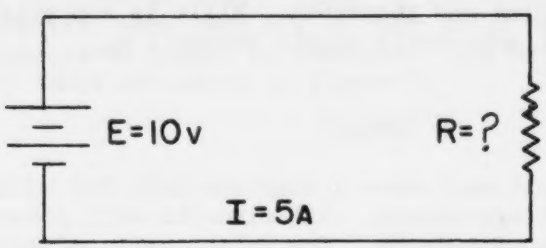
2.



I = _____amps

3. _____ is the opposition to the flow of electrons through an electric circuit.

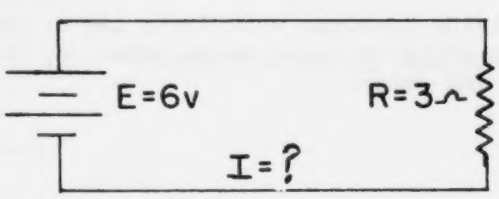
4.



R = _____ohms

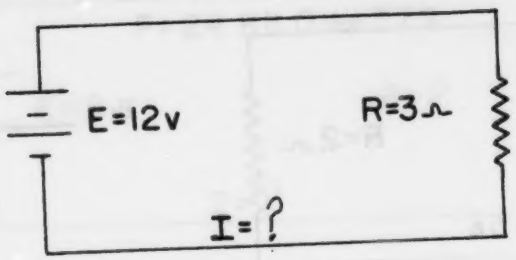
5. The amount of current in a circuit can be _____ by increasing the amount of voltage applied to the circuit.

6. a.



I = _____amps

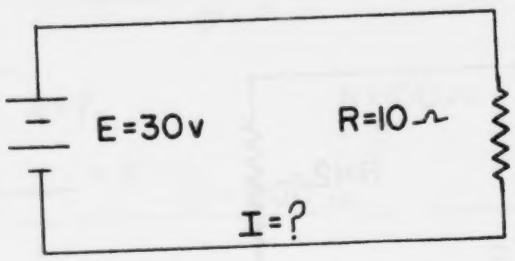
b.



I = _____amps

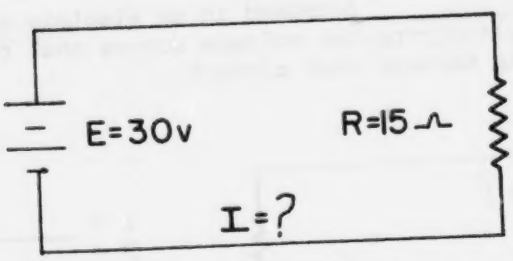
7. The amount of current in a circuit can be _____by increasing the amount of resistance present in the circuit.

8. a.



I = _____amps

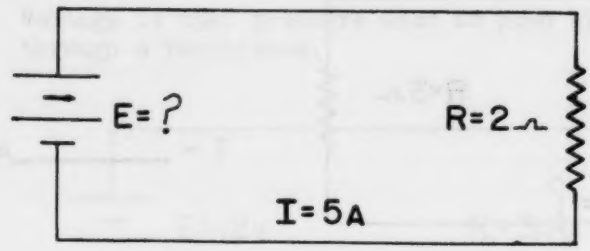
b.



I = _____amps

9. When the amount of current flowing in a circuit, and the amount of resistance present in that circuit are both known, the amount of _____ applied to that circuit can be found by using Ohm's law.

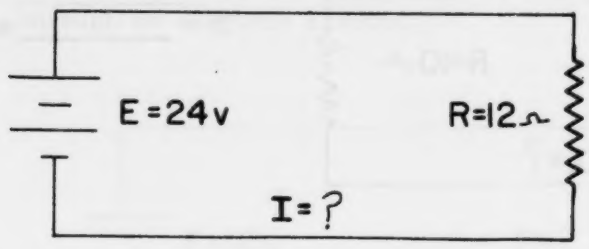
10.



E = _____volts

11. When the amount of voltage applied to a circuit, and the amount of resistance present in that circuit are both known, the amount of _____ flowing through that circuit can be found by applying Ohm's law.

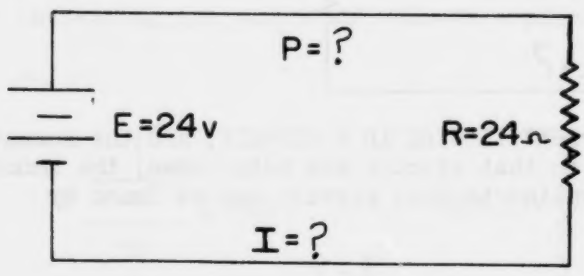
12.



I = _____amps

13. The amount of _____ consumed in an electric circuit can be found by multiplying the voltage across that circuit by the current passing through that circuit.

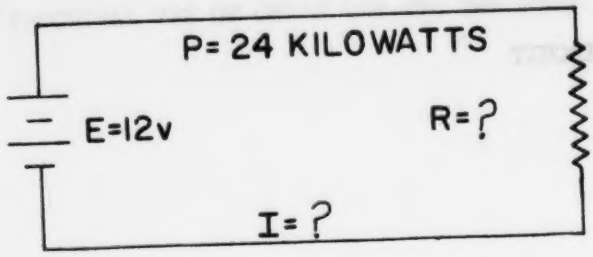
14.



I = _____amps
P = _____watts

15. The value of 80,000 watts written in terms of the metric system would be 80 _____watts.

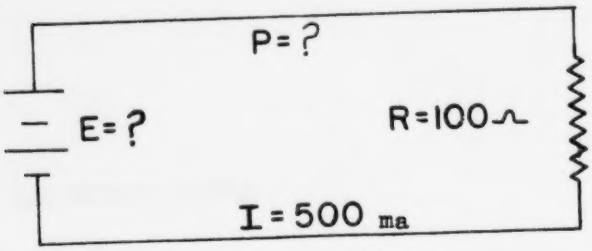
16.



R = _____ ohms
I = _____ amps

17. The value of .000001 amperes written in terms of the metric system would be 1 _____ ampere.

18.



E = _____ volts
P = _____ watts

STUDENT NOTES

INTRODUCTION

DEVELOPMENT

1. SIMPLE ELECTRIC CIRCUIT

2. OHMS LAW

3. POWER FORMULA

4. PRACTICAL USE OF OHM'S LAW AND THE POWER FORMULA

5. THE METRIC SYSTEM

SUMMARY

☆U.S. Government Printing Office: 1986—491-036/52448